How Do Trees Know When to Start and Stop Growing?  
And How Will That Change in the Future?

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Phenology
The study of recurring biological events
• Budburst (height growth initiation)
• Diameter growth initiation & cessation
• Flowering
• Insect hatches
• Bird migrations
• And many other events
Today’s Roadmap

Overview of cues which start and stop tree growth

Predictions of changes based on models we developed

Seedlot Selection Tool example

Very little on data sources or model development (see literature!)
When should a tree start growing in the spring?

• Late enough to avoid frost
• Early enough to take advantage of favorable growing conditions
When should a tree **stop** growing in the fall?

- Early enough to avoid frost
- Late enough to take advantage of favorable growing conditions
PNW tree species, especially Douglas-fir
Methods

- Field sites
- Seed sources
- Controlled environments

- Height-growth initiation
- Diameter-growth initiation and cessation
What’s known about tree growth initiation – temperature cues

• Exposure to warm temperatures (“forcing”)
• Amount of forcing required depends on exposure to cool temperatures (“chilling”)

The “possibility line”

Based on published work for PNW species
Many combinations can result in spring budburst.

Shape of curve depends on species and event – asymptote implies plant requires chilling.
Chilling and Forcing Effectiveness

35-45 °F most effective for chilling

Freezing temps

Warmer temps not very effective
No evidence for photoperiod effect on DF initiation*

Most trees do NOT use calendars!

Some will respond to long photoperiod if not chilled (don’t know of any PNW species that do tho)

Also see Laube et al. 2014, Global Change Biology

* No evidence for Oregon oak either
Models can be used to predict dates of BB in past as well as future.

Predicted date of budburst for Douglas-fir at Olympia and Salem based on historical weather records.

2 days earlier date of BB/decade in Salem over 60+ years.
Which families/regions had EARLIEST budburst in 2010?

Early Budburst: Top Row = Earliest Budburst

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- **CA Sierra** = Pink
- **CA coast** = Light Blue
- **ORSISL** = Yellow
- **CA Klamath** = Purple
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= WA coast
= OR coast north
Possibility lines differ by event
Seasonal Patterns of Height & Diameter Growth

2012, Douglas-fir, WACST, Buckhorn
2015 was 3.9 °F (2 °C) warmer than 1950-2000 mean.

**RCP =** Representative Concentration Pathways
We appear to be on the 8.5 line (emissions continue to rise all century)
DF height-growth initiation

Change in days

Earlier

Later

Aug 14

Jun 1

Mar 18

1981-2010

2071-2100

(RCP 8.5)
DF diameter-growth initiation

Change in days

earlier

later

Aug 14
May 15
Feb 12

1981-2010
2071-2100
(RCP 8.5)

N

-71

-36

0

33
Change in frost risk following growth initiation

Change in hours < -2°C

Height

Diameter

Dark blue = more hours of frost

Predicting mean risk – not extreme events

-2 °C = 28 °F
Δ % favorable conditions after growth initiation

Based on AET (Actual evapotranspiration – uses soil as well as climate data)

Dark blue = less time for favorable conditions
Start in DF height growth with climate

Δ % of favorable AET

Change in date

Δ from 2081-2010 to 2071-2100
Start in DF diameter growth with climate change in date from 2081-2010 to 2071-2010.
Douglas-fir -- very low chilling

Branches developed from lateral buds and are out-growing former terminal

Terminal bud previous year did not burst

DF terminal buds more sensitive than lateral buds to lack of chilling - effect differs by species
Grand fir

Low chilling

High chilling

Mean winter temp 50s °F (10+ °C)

Mean winter temp 40s °F (4-9 °C)
Lodgepole pine

Low chilling

High chilling
Western white pine

Low chilling

High chilling
Pacific madrone

Low chilling

High chilling
Western redcedar

Low chilling

High chilling
Different line shapes imply species will differ in response to low chilling.
Change in Date of BB by 2080

Western Redcedar  Western Hemlock  Pacific Madrone
Line shapes can differ by seed source as well as species.
Conclusions for Growth Initiation

• TEMPERATURE Driven (both chilling and forcing)

• Growth start may lag at low lat & elev limits

• Projected to track climate change at higher latitudes/elevations

• Risk of > frost exposure possible, but minor

• Reduced season for favorable AET in places

• Ht- & diam-growth start follow similar patterns, though diam growth lags more
When should trees **STOP** growing?

Stop before fall frosts (but continue as long as possible)

Generally assumed to rely on photoperiod and temperature – but not well modeled

Tree phenology mostly studied in spring events
Short photoperiods and low mean temperatures both increase likelihood of diameter shutdown.

Based on >40 site x year combinations for DF in the field, Ms submitted for publication.
Phytochromes - Pigments sense light quality/quantity

Trigger changes:
  Seed & bud dormancy
  Stem elongation
  Flowering

Legris et al 2016, Jung et al. 2016 indicate that rate of change from one phytochrome form to another is TEMPERATURE dependent. Thus, PCs could account for both daylength and temperature effects.
Diameter-growth cessation

Diameter-growth cessation date

(a) Current climate
(b) Future climate
(c) Change
(d) Genetic variation

(RCP8.5)
Summer cessation of diameter growth – Medford 2015

40 °C = 104 °F

early summer heat wave
Summer diameter-growth Cessation

Long days and high daily max temperature can trigger early cessation

Long days = short nights to allow recovery

Model based on 1 years data only

40 °C = 104 °F
Mechanisms for Summer **Cessation**

Reduction/cessation mitosis $> 40^\circ$C

Production **heat shock proteins** in leaves on days with high thermal stress

Reduce transport of plant hormones

Long days = fewer hours to recover

May induce bud dormancy similar to heat-induced dormancy in seeds
Type of Growth-Cessation

(a) Current climate  (b) Future climate

Modeling “summer” cessation based on limited data but important topic

Working on controlled environment study now

Could also study tree rings
Growth-Cessation Date

(c) Current climate
(d) Future climate
(e) Change

Date:
- May 18
- Aug 10
- Nov 2

1981-2010
2071-2100

Days:
-63
-155
29
Wrap up – HT Initiation

Budburst or height initiation tracks future climate except in the warmest parts of DF range

Species differ - some have strong chilling requirement (DF, true firs, some pine) but not others (WRC, madrone)

Also, some species have different responses term & lat buds

Frost – a concern – but not for average events
Wrap up - Diameter growth

**Initiation** does not require the same chilling as BB
Starts 6-8 weeks earlier
Growth start tracks temp fairly well but loses some favorable conditions in warmer/drier areas

**Cessation** - Ends later at high latitudes, cool climates
Limited by photoperiod at low latitudes
May **TIP** to summer cessation with very high temperatures
Final Thoughts

Modeling of precip & extreme temps less developed that for mean temp

Insects, diseases, fires interact/alter tree responses

Managers will have more flexibility in cooler climates for selecting species to favor
Final Thoughts

Future responses could be incremental or have tipping points (e.g., diameter growth cessation)

Earlier cessation could alter future drought resistance if less latewood, not just diameter growth
1. Are native populations adapted to current and future climates?
2. If not, how far do we have to go to find populations adapted to a planting site (assisted migration)?

Search for Conservation Biology Institute
Then look for Seedlot Selection Tool
Webinar on how to use it
App is online
Trends in winter temperature and precipitation at Buckhorn

**MCMT 1975-2085 at Buckhorn**

Increase 6°F

**Change in MCMT since 1975 at Buckhorn**

**MAP 1975-2085 at Buckhorn**

Increase 2.5”

**Change in MAP since 1975 at Buckhorn**
Seedlots for Soda320

Select objective
Find seedlots
Find planting sites

Select planting site location
Locate your planting site
Use the map or enter coordinates

Elevation: 2848 ft

Select climate scenarios
Which climate are the seedlots adapted to?
1961 - 1990

When should trees be best adapted to the planting site?
1961 - 1990

Select transfer limit method
Custom
Zone

Select climate variables
Units: Metric

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</tr>
</thead>
<tbody>
<tr>
<td>MMT</td>
<td>1.7°C</td>
<td>180.0°C</td>
</tr>
<tr>
<td>MAP</td>
<td>2001 mm</td>
<td>500 mm</td>
</tr>
</tbody>
</table>

Run Tool

Map your Results

Past Climate
Seedlots for Soda320

Recent Climate
Seedlots for Soda320

2025 Climate RCP8.5
Seedlots for Soda320

Select objective
- Find seedlots
- Find planting sites

Select planting site location
- Locate your planting site
- Use the map or enter coordinates

Select climate scenarios
- Which climate are the seedlots adapted to?
  - 1961-1990
- When should trees be best adapted to the planting site?
  - 2041-2070
  - RCP8.5

Select transfer limit method
- Custom
- Zone

Select climate variables
- Units: Metric/Imperial
- Name | Center | Transfer limit (+/-)
- MGT | 4.2°C | 8°C
- MAP | 2071 mm | 500 mm

Map your Results
- Run Tool
- Save Last Run
- Export PDF

2055 Climate
RCP8.5
Seedlots for Soda320

Select objective
- Find seedlots
- Find planting sites

Select planting site location
- Locate your planting site
- Use the map or enter coordinates
  - Lat: 44.4346
  - Lon: -122.2420
  - Elevation: 2848 ft

Select climate scenarios
- Which climate are the seedlots adapted to?
  - 1961 - 1990
- When should trees be best adapted to the planting site?
  - 2071 - 2100
  - RCP8.5

Select transfer limit method
- Custom
- Zone

Select climate variables
- Units: Metric
- Name | Center | Transfer limit
- MAST | 5.7°C | 4.1°C
- MAP | 2048 mm | 500 mm

Map your results
- Run Tool
- Save Last Run
- Export PDF

2085 Climate RCP8.5
There are risks and costs to a program of action. But they are far less than the long range risks and costs of comfortable inaction.

John F. Kennedy (May 12, 1961)
Acknowledgements

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• Lone Rock Timber Co.
• Port Blakely Tree Farms

• Roseburg Resources
• Starker Forests
• USFS Stone Nursery
• Washington DNR

Our coworkers rock!!!
Douglas-fir Seed Transfer Zones for Oregon (Randall 1996)
Progress, But Always More to Learn
Regions with high Rhabdocline were early in spring budburst dates.

Nick Wilhelmi June 2016 thesis on needle cast diseases, OSU
Height  Cessation

Next research topic

Bud set and cessation of growth are not the same as substantial growth can occur after bud scales are formed and a bud is set.

Data from repeated measurements or TL cameras look at cessation – but not budset.
Possibility lines (CE studies allow us to peer into future)
Douglas-fir Seed-Source Movement Trial

Each location has a different landowner

Harrington and St. Clair, PNWRS
DF reproductive phenology also has a possibility line

Graph courtesy of Janet Prevéy
Other Species Also Begin Diameter Growth Prior to Ht Growth

- Sitka spruce
- Western redcedar

**Western redcedar height growth initiation**

**Sitka spruce budburst**